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The Device Parameters Simulation of Electrical Fast Transient Generator

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Abstract

With the development of the electronics, communication and the wide application of computer technology, electrical and electronic products are widely used in industrial and military field. In our daily life, there is a wide range of electromagnetic interference. The electrical fast transient generator is to verify the electromagnetic susceptibility of modern electronic equipment to transient-conducted interference. This paper proposes mathematical model of electrical fast transient generator and pays attention to the device parameters by PSPICE.

Keywords: Electrical fast/burst transient, PSPICE, EMC

1. Introduction

Electrical fast transient generator is used for determining instability of any electronic device during the design process. A burst of very fast pulses are usually associated with switching circuits, such as relay contact bounce, fluorescent lights and so on. Experiments show that these actions may produce much pulse interferences. For example, the amplitude of peak pulse may reach to 500-3000v and the number of peak pulse string may reach to 720 when the signal relay act. All digital systems and analog signal processing can fail when affected by fast transient bursts. According to the study, this kind of interference is characterized by pulse in groups, higher pulse repetition frequency and short pulse rise time. But the energy of a signal is small, so it usually does not cause equipment failure, but the equipment malfunction is often visible. EFT generator is used to simulate the interference signals, to determine equipment immunity to upset, it is widely used in industrial electronics, communication, medical electronics, home appliances, office automation and other fields of electromagnetic compatibility design, certification, manufacturing evaluation, diagnosis and testing.

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International Electrotechnical Commission (IEC) for electrical fast transient have specific technical requirements, which pulse rise time and pulse duration are two of the most important parameters. Because a single pulse reaching to forefront costs 5 ns, means that the frequency of the harmonic component is at least 60MHz. Therefore, the selected burst generator device parameters and circuit parameters will bring significant impact to the waveform of the generator. So it is necessary to study the parameters of the generator.

This paper first presents an overview of EFT, and introduces the standards of the generator, then proposes a pulse generator equivalent circuit. After analysis of circuit parameters, the simulation software PSPICE would be used to verify which parameters would be important to the waveform of the generator and what change would improve the performance of the electrical fast transient generator.

2. The Standards of Electrical Fast Transient Generator

International Electrotechnical Commission (IEC) has enacted a standard about electrical fast burst—IEC61000-4-4, our country has also developed a corresponding standard—GB/T17626.4. IEC's standards for Electrical fast transient generator are [1]:

- The maximum energy: 50Ω load 2Kv when 4MJ/pulse.
- The dynamic between the source impedance:1-100MH
Z to 50Ω±20%.
- The generator internal DC blocking capacitor: 10nF.
- Pulse rise time: 5ns±30%.
- Pulse duration: 50ns±30%.

Significant parameters for the test are the short rise time, the repetition rate and the low energy of each pulse [2].

The standard of electrical fast transient are [3]:

- A single pulse waveform shown in Figure 1, where the pulse rise time is 5ns and the duration (full width at half maximum) is 50ns.

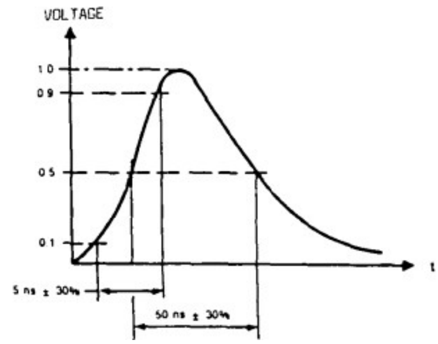

Fig. 1.A single EFT pulse.

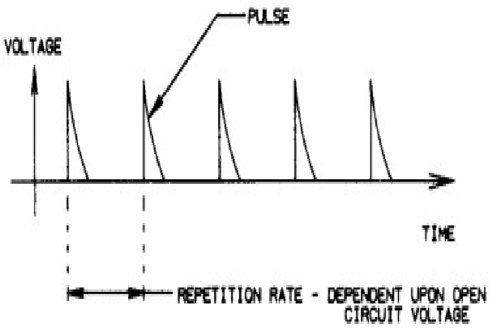

Fig. 2. Repetition rate.

- The repetition rate, shown in Figure 2.
- The burst duration, shown in Figure 3

The repetition rate is not specified. However, the duration of the burst and the interval between bursts are specified. Each pulse has a slow rise ending in an abrupt collapse. Because the pulses occur in bursts, these single pulses have the same effects as pulses with fast rise time and slower decay.

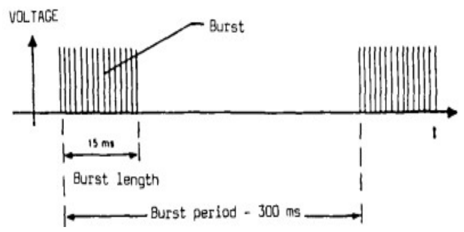

Fig. 3.Burst duration and burst period

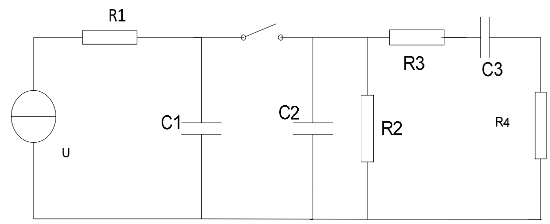

Fig. 4.Waveform circuit diagram.

3. Parameters Analysis

3.1. The simplified circuit diagram

Electrical fast transient generator is an signal simulator used for generating the burst disturbance.
The simplified circuit diagram of the EFT generator is shown in Fig 4.
First, the capacitor must be charged to certain value while the triggered is closed.
Equation (1) shows the voltage on capacitor C_1 when the capacitor is charging. It would cost 3τ to 5τ.

$$U_{C_1} = U \times (1 - e^{-\frac{t}{R_1 \times C_1}}) \tag{1}$$

$$\tau = R_1 \times C_1 \tag{2}$$

The switch K would be triggered when the energy storage capacitor C_1 is charged to certain value. So high-voltage nanosecond pulse would be observed on the load. The switch K would be closed when the energy of C_1 is not enough. Then, the capacitor begin to discharge. Referring to (3), the voltage on the resistor R_4 is:

$$U_{R_4} = U_{C_1} \times (1 - e^{-\frac{t}{R \times C_1}}) \tag{3}$$

$$R \approx R_2 // (R_3 + R_4) \tag{4}$$

According to the above discussion, the fundamental process, also the oscillation process of the generator, are mainly determined by the charging and discharging energy-storage capacitor.
Fast burst of a single electrical pulse is a double exponential decay pulse, shown in (5):

$$U_{R_4} = K \times (e^{-\frac{t}{\tau_1}} - e^{-\frac{t}{\tau_2}}) \tag{5}$$

where K is a proportionality constant, τ_1 , τ_2 with the pulse rise time, duration, corresponding to the constant of proportionality.
The literature [6,7] propose that the electrical fast transient pulse rise time is:

$$t \approx 2.3 \frac{L}{R} \tag{6}$$

3.2. The features of the parameters

The generator produces transient pulses with stable parameters, but it is important to choose proper elements in order to achieve reasonable parameters of single pulse. Only the impedance matching resistor (50Ω) and the DC blocking capacitor C_2 (10nF) are fixed.

Because a single pulse burst reaching to forefront costs 5ns. Referring to (7), the frequency of the harmonic components is larger than 60MHZ.

$$f = 1/\pi t = 1/3.14 \times 5 \times 10^{-9} \tag{7}$$

As shown in (8), the wavelength is about 5m.

$$\lambda = c/f = 3 \times 10^8 / 60 \times 10^6 = 5m \tag{8}$$

So as long as the length of the wire is long enough, the high frequency components may overflow. Once a signal overflow, the shape of the waveform may distort.

For high-frequency, the length of the wire reflect the size of distribution parameters. For example, a wire of 10mm has self-inductance of 15nh. So in the process of waveform transferring, parasitic parameters would bring great influence to the forming of the output pulse shape: the inductance of the generator circuit, is not specified, although it directly affects the pulse rise time. Therefore, the circuit resistors and capacitors must have a corresponding request.

All conductors are inductive, and at high frequency, the inductance of even quite short pieces of wire or printed circuit traces may be important. The inductance of a straight wire of length of L mm and circular cross-section with R mm in free space is given by the first equation shown in Figure5:

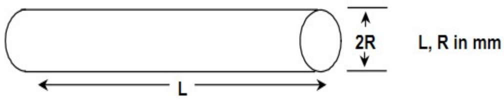

Fig. 5.Wire sample

$$\text{Wire inductance} = 0.0002 \times L \times [\ln(\frac{2L}{R}) - 0.75] \times \mu H \tag{9}$$

According to (9), we could calculate the inductance of the wire. On the basis of equation (6), the inductance is important to the pulse rise time.

C_1 is the main capacitor—energy storage capacitor which determines the energy of single pulse; R_1 is current limiting resistor which controls the speed of charging and limits the loop current; R_2 is the resistor which determines the shape of the pulse. In most cases, we could neglect the parasitic capacitor C_2 . R_3 is impedance matching resistor; C_3 is blocking capacitor, isolating the DC component and the is the terminal resistor.

Resistor must be in a certain range. The resistor have no relationship with the voltage and frequency, but the parasitic inductance and parasitic capacitance must be very small.

Therefore, compared to other type of resistor, metal film resistor would be recommended [8], which have good high frequency response. For capacitors, on the premise of bearing enough voltage, inherent inductance must be small as soon as possible.

4. Simulation

According to the standard, the resistor R_4 is set to 50Ω [9]. And the biggest energy of a single pulse is 4MJ when the voltage source is 2KV, so the capacitor C_1 is no more than 2nf. Among them, the pulse capacitor is set to 300pf, circuit stray inductance is set to 400nh, pulse forming resistor is set to 500Ω.The trigger is closed at 500ns so that the capacitor has enough time to charge to certain value.

After using these devices which we talk above, electrical fast transient generator is equivalent to the following circuit, shown in Figure 6:

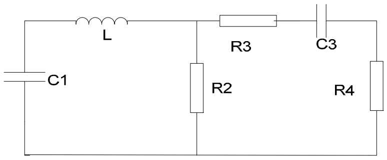

Fig. 6.Simplified equivalent circuit diagram.

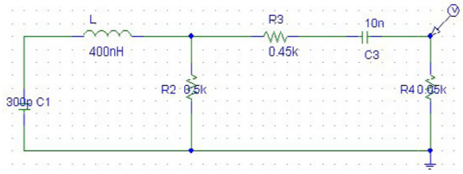

Fig. 7.The model in the Pspice.

As shown in Fig. 6, there is no voltage source in the diagram, and we set the initial voltage of the capacitor 2KV, here we consider the case of discharging one time.

And L is the total inductance of the discharging circuit, including wire inductance and switch inductance; R_4 is the load resistor.

The model set in pspice is shown in Figure 7.Standard set forth in the 50Ω matched load, 2KV the maximum single pulse energy 4mJ. Among them, the pulse capacitor is set to 300pf, circuit stray inductance is set to 400nh, pulse forming resistor is set to 500Ω.

4.1. The initial simulation

The waveform from 0-200ns is obtained in Figure 8 when we choose the proper parameters. As shown in Figure 8, the pulse rise time is about 5ns,the width of the pulse is about 50
ns, so the parameters we select basically meet the requirements.

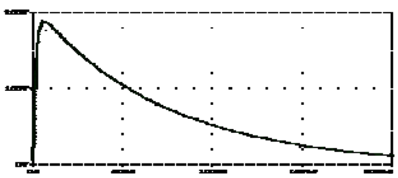

Fig. 8.Simulation results between 0-200ns.

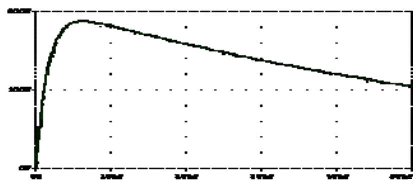

Fig. 9.Simulation results between 0-50ns.

4.2. Simulation of pulse rise time

With the purpose of finding which parameter would influence the steepness of the pulse. So we can shorten the pulse rise time. We could reduce the observation period from 200ns to 50ns, the result is shown in Figure 9.

We have discussed the pulse rise time is determined by the total inductance of the discharging circuit. So we reduce L from 400nh to 200nh and other parameters do not change. The result is shown in Figure10, we could find that the pulse rise time is no more than 5ns and the pulse is more steeper. So the result proves the correctness of discussion above.

4.3. Simulation of pulse width

In order to find which parameter would influence the dropping of voltage on the load. We reduce the observation period from 200ns to 100ns. The result is shown in Figure11.

In this part, we must pay more attention to the value on the Y-axis. In order to change the pulse duration, we try to raise resistor R_2 to 2KΩ and other parameters do not change. The observation period is 0-100ns. The result is shown in Figure12. Compared to Figure11, we can find that the falling altitude of the voltage on the load is no more deeper than before.

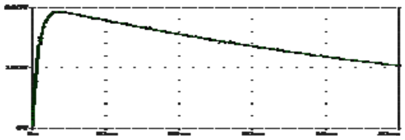

Fig. 10.As the inductance is reduced, the simulation results is obtained between 0-50ns

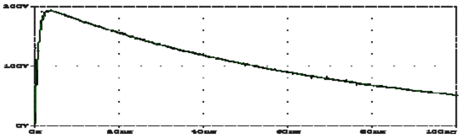

Fig. 11.Waveform between o-100ns.

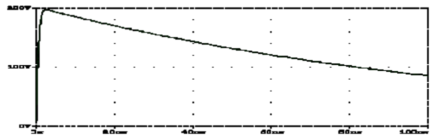

Fig. 12.As the resistor is upgraded ,simulation result is obtained between 0-100ns.

5. Conclusion

Although this paper discusses the case of discharging only once, we could investigate the relationship between various components. Only the specific parameter could influence the waveform of the generator.

According to the simulation results, we should choose suitable parameters in order to satisfy the requirements of the standards. Lower capacitance can improve the steepness of the pulse while suitable resistor R can improve the pulse width. Therefore, different voltage levels need to select the suitable parameters to waveform standards.

Acknowledgements

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